



TPF Interferometer Architecture

Serge Dubovitsky

Jet Propulsion Laboratory

TPF Expo

October 14, 2003

1. Architecture Options
2. Figures of Merit
3. Strawman Configurations



Architecture Studies Objective

JPL

Terrestrial Planet Finder Mission

TPF

Science Performance

Implementation Platform

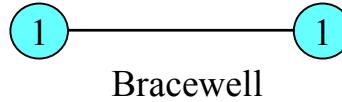
Architecture

Minimum Science Mission (~30 stars)

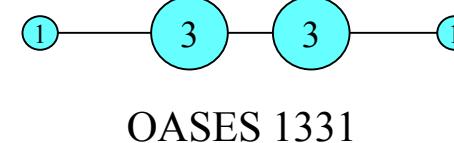
Full Science Mission (~150 stars)

Structurally Connected Interferometer (SCI)

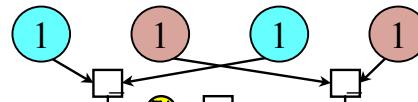
Formation Flying Interferometer (FFI)



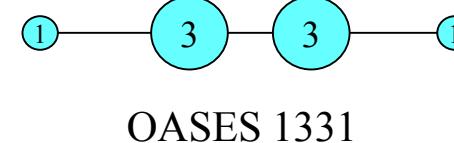
Bracewell



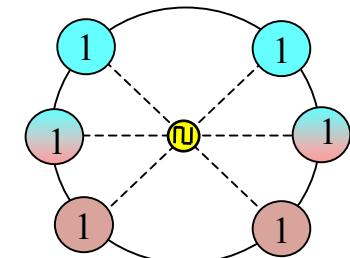
OASES 1331



Dual Chopped Bracewell (DCB)



Chopped Degenerate Angel Cross (DAC)



Darwin:
bow-tie

A NASA
Origins
Mission

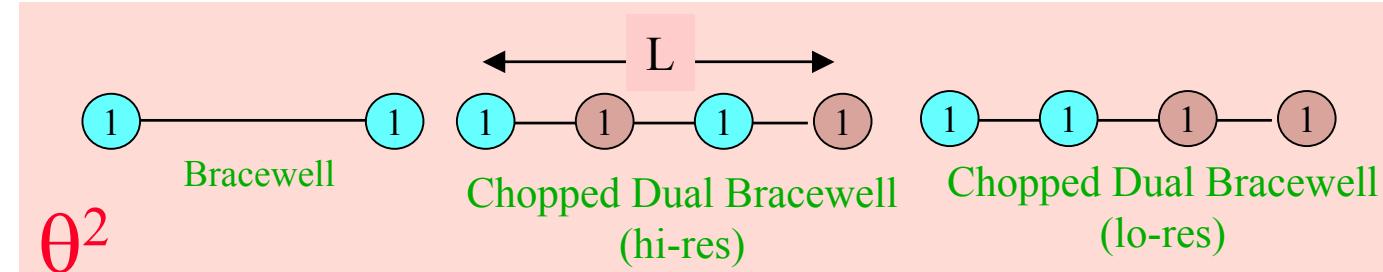
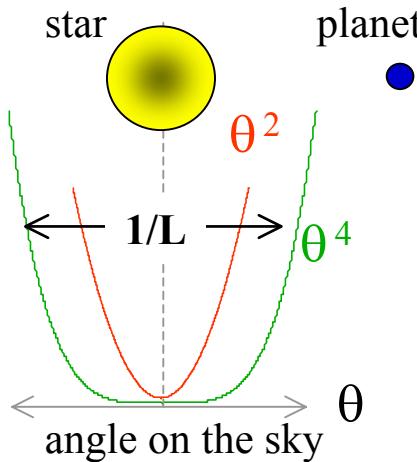
•Choose an Architecture to support each of the two missions



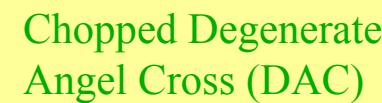
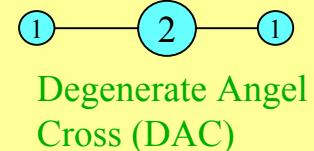
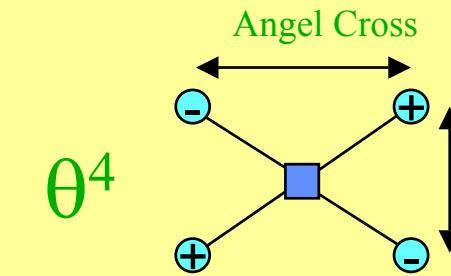
Nulling Architecture Options

JPL

Terrestrial Planet Finder Mission



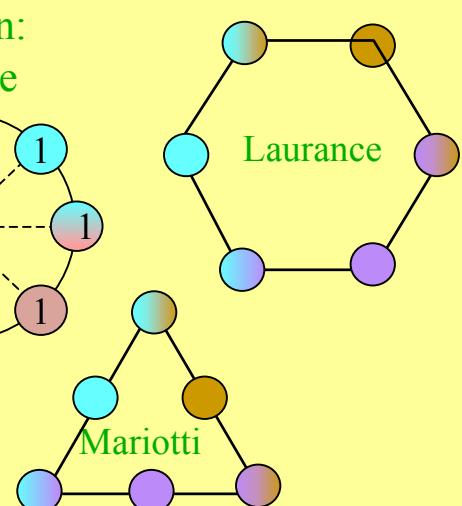
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Degenerate Angel Cross (DAC)

Chopped Degenerate Angel Cross (DAC)

Darwin:
bow-tie

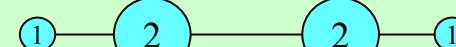


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Origins
Mission

θ^6



OASES 1331



OASES 1221



Key Figures of Merit

JPL

Terrestrial Planet Finder Mission

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Origins
Mission

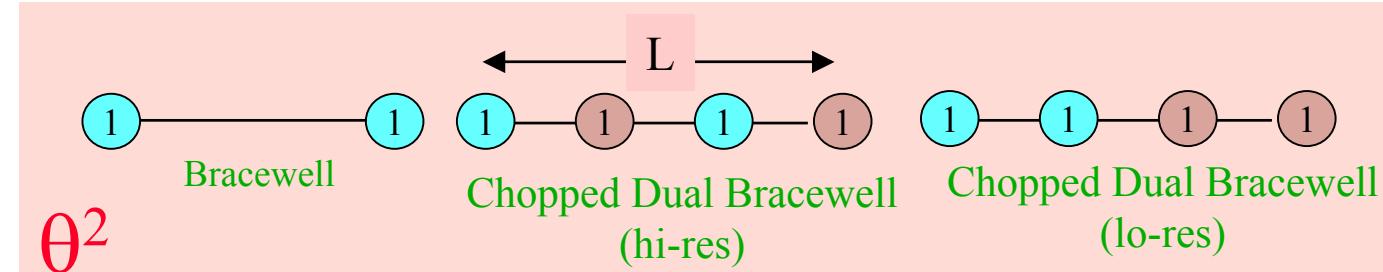
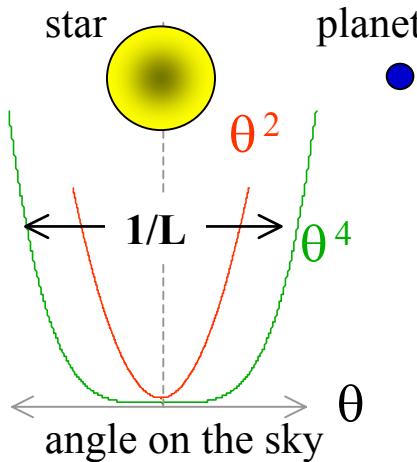
- Ability to isolate planet signal
 - Exo-zodi suppression
 - Instrumental background suppression
 - Practical Configuration
 - Ability to examine an adequate number of stellar systems
- Phase Chopping**
- Beam combiner complexity**
- Resolution and Sensitivity**



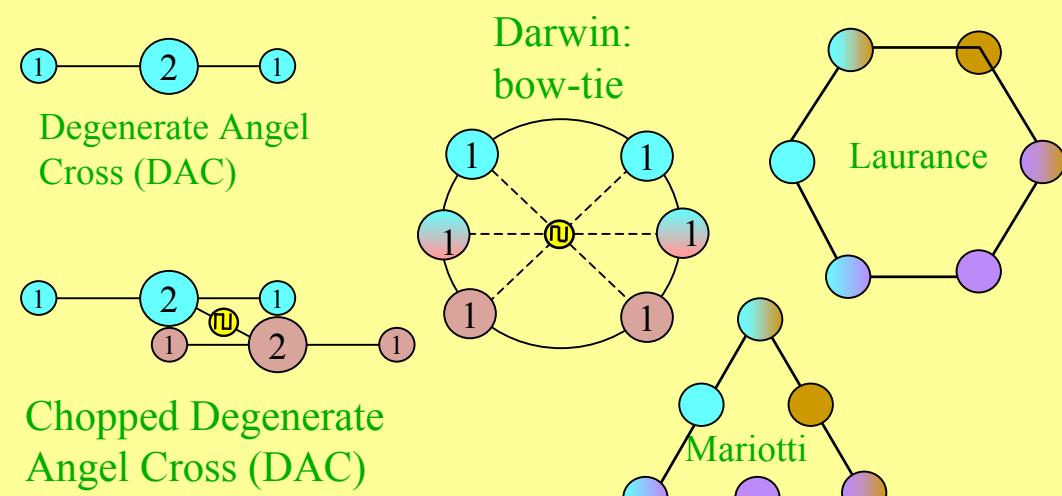
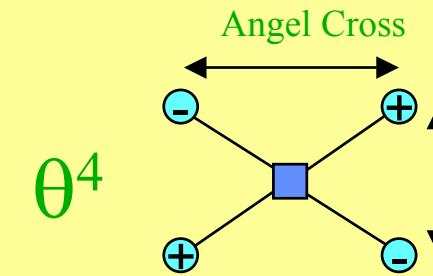
Nulling Architecture Options

JPL

Terrestrial Planet Finder Mission



TPF

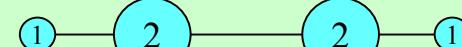


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Mission

θ^6



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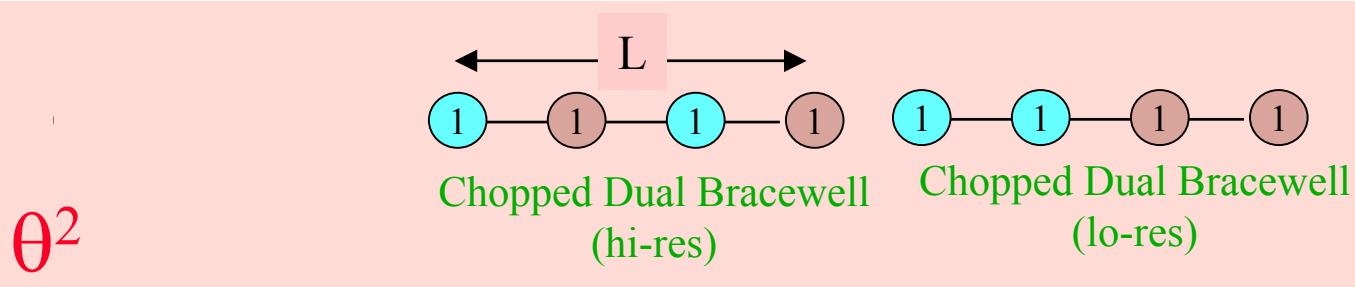
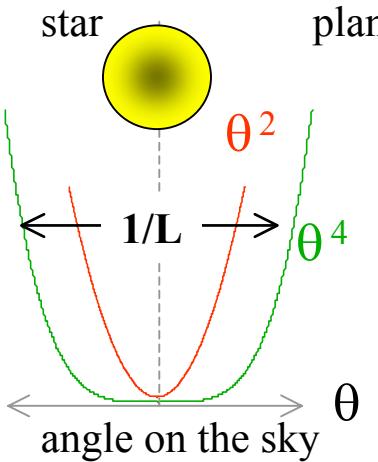
OASES 1221



Nulling Architectures Options that Support Phase Chopping

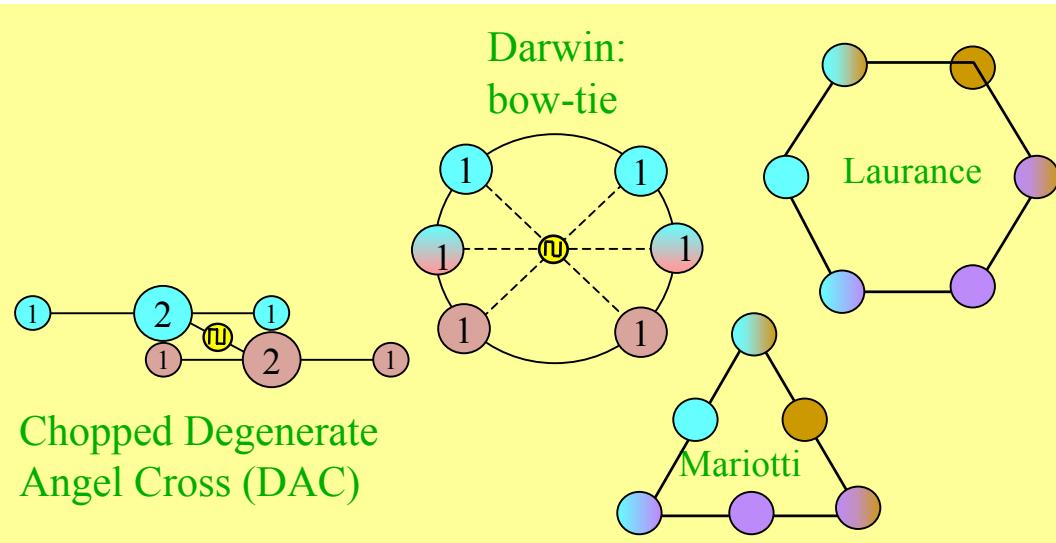
JPL

Terrestrial Planet Finder Mission



TPF

θ^4



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Mission

θ^6



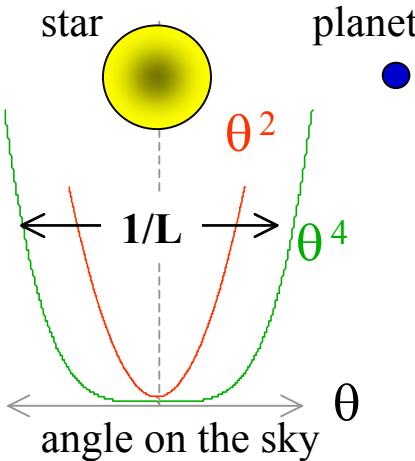
Nulling Architectures Options Considered in Detail

JPL

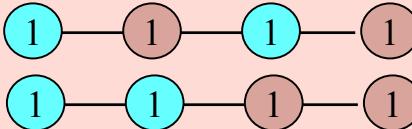
Terrestrial Planet Finder Mission

TPF

A NASA
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Mission

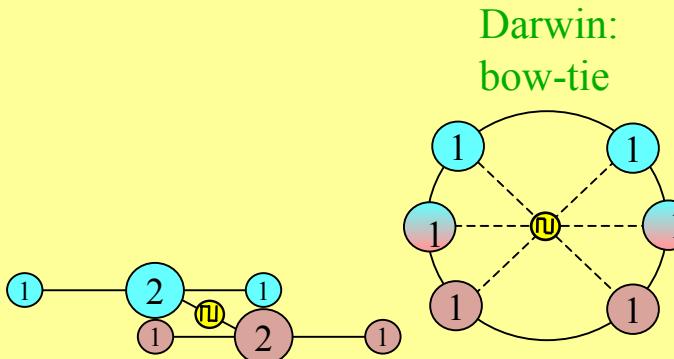


$$\theta^2$$



Hi-Lo-Res Chopped Dual Bracewell

$$\theta^4$$



Darwin:
bow-tie

Chopped Degenerate
Angel Cross (DAC)

$$\theta^6$$



Key Figures of Merit

JPL

Terrestrial Planet Finder Mission

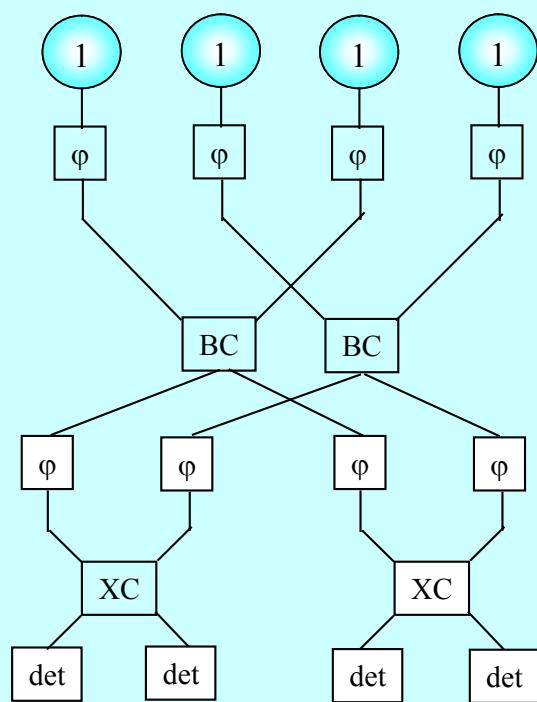
TPF

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Mission

- Ability to isolate planet signal
 - Exo-zodi suppression
 - Instrumental background suppression
 - Practical Configuration
 - Ability to examine an adequate number of stellar systems
- Phase Chopping**
- Beam combiner complexity**
- Resolution and Sensitivity**

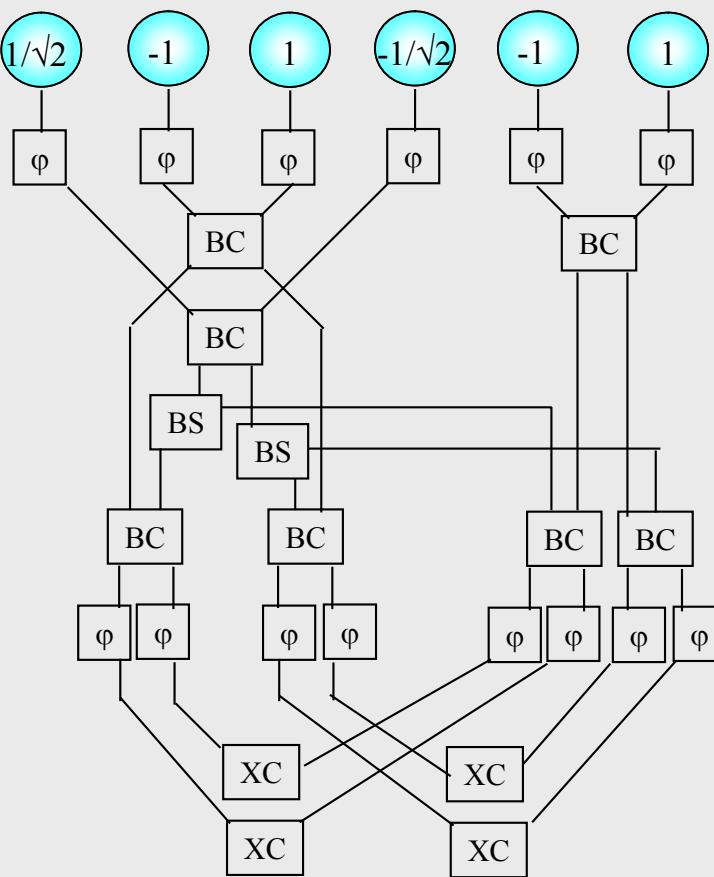
Beamcombiner Complexity

Dual Chopped Bracewell
(hi-res)

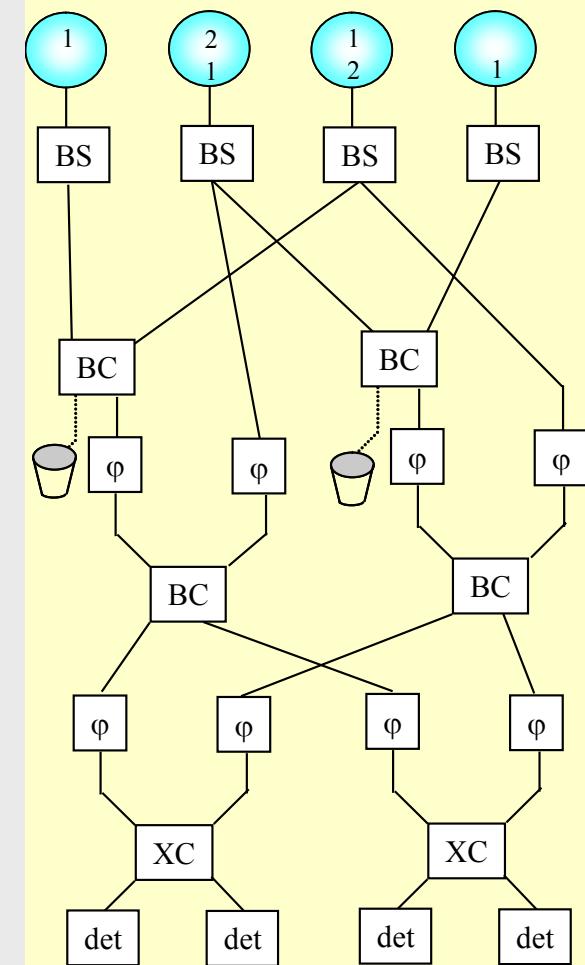


Simplest

Darwin Bow-tie



Chopped DAC





Key Figures of Merit

JPL

Terrestrial Planet Finder Mission

TPF

- Ability to isolate planet signal
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Minimum Science Mission (~30 stars)
Full Science Mission (~150 stars)

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Performance Models

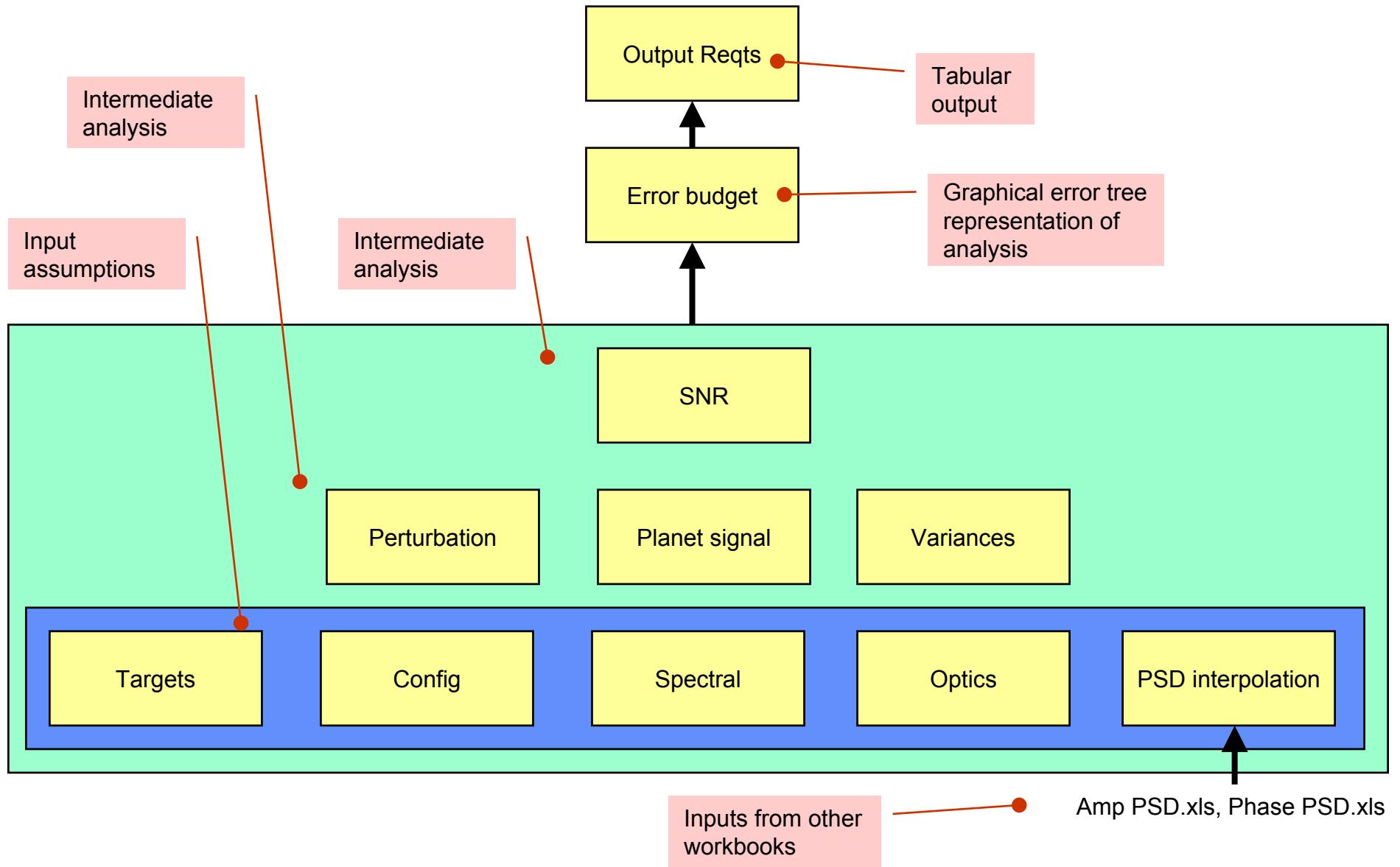
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Terrestrial Planet Finder Mission

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- **Interferometer Performance Model (IPM): SNR for a single star**
 - Rigorous mostly analytical model of a single observation
 - Level 3 engineering requirements (e.g. phase and amplitude PSD)  SNR for a canonical planet (Earth-sun at 10 pcs)
 - Excel spreadsheets or MatLab, supported by documentation of analysis
- **Star Selectors Analysis: number of stars in a mission lifetime**
 - Analytical parametrized model of the instrument sensitivity and resolution (based on the IPM)
 - Accounts for non-SNR limitations of the instrument
 - Works on the entire star list to determine the number of measurable stars
 - MathCad worksheet



Interferometer Error Budget Top Level Worksheet





Performance Models

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Terrestrial Planet Finder Mission

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Mission

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Star Selectors Analysis

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Terrestrial Planet Finder Mission

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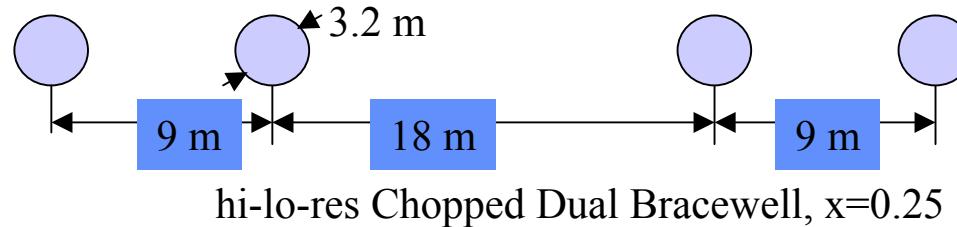
	Value	Selected Stars	Remaining Stars
TPF Project Star Selectors			
Stars within	30 parsecs		
Abundance Filter	Ebbets list		258
Type	FGK	250	250
Binarity (planet formation)	TBD		
TPF Interferometer Star Selectors			
No Binary Companion (planet det.)	<10 asec	228	220
Field Of Regard	+/- 45°	181	151
Resolution	36 m uneven DCB	116	63
Integration Time	3.2 m apertures,		
Detection	50% of 2 years		54
Spectroscopy ($\eta_{\text{earth}}=0.1$)	50% of 3 years		5



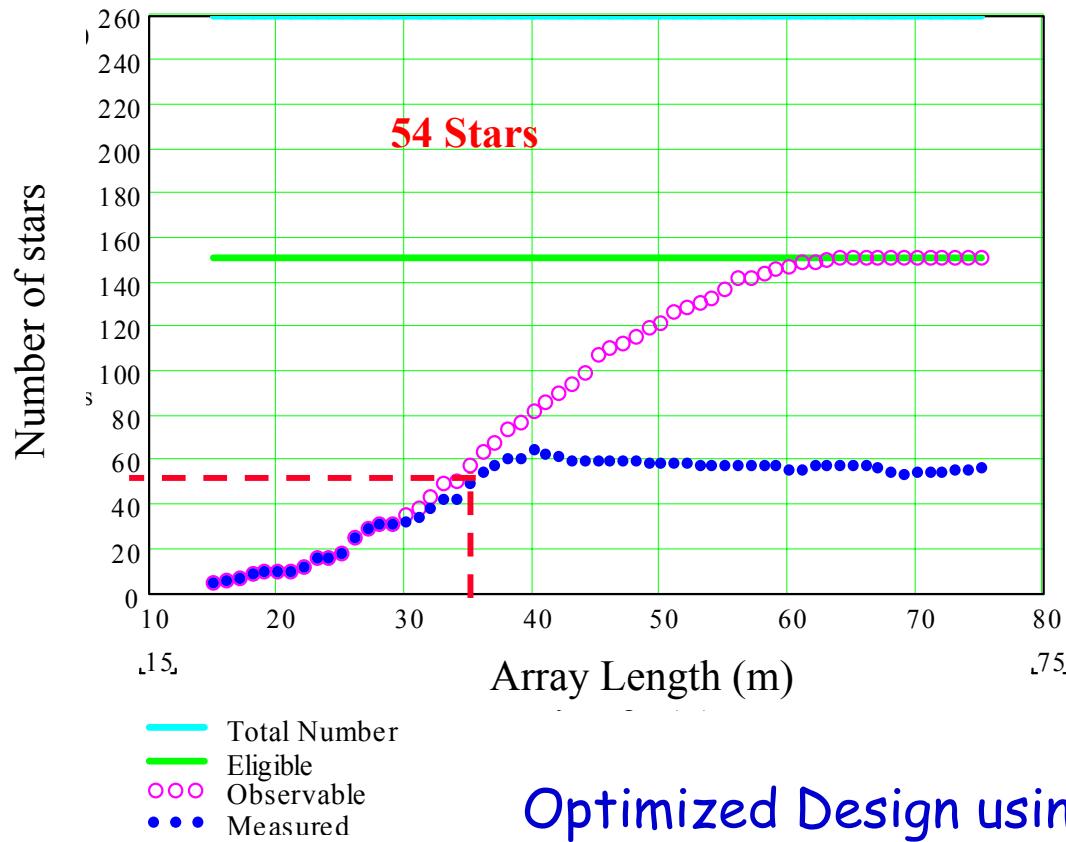
Minimum Mission Strawman

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Terrestrial Planet Finder Mission



- 36 m Array Length Structure
- 3.2 m apertures
- Uneven Dual Chopped Bracewell



Optimized Design using Star Selectors Analysis

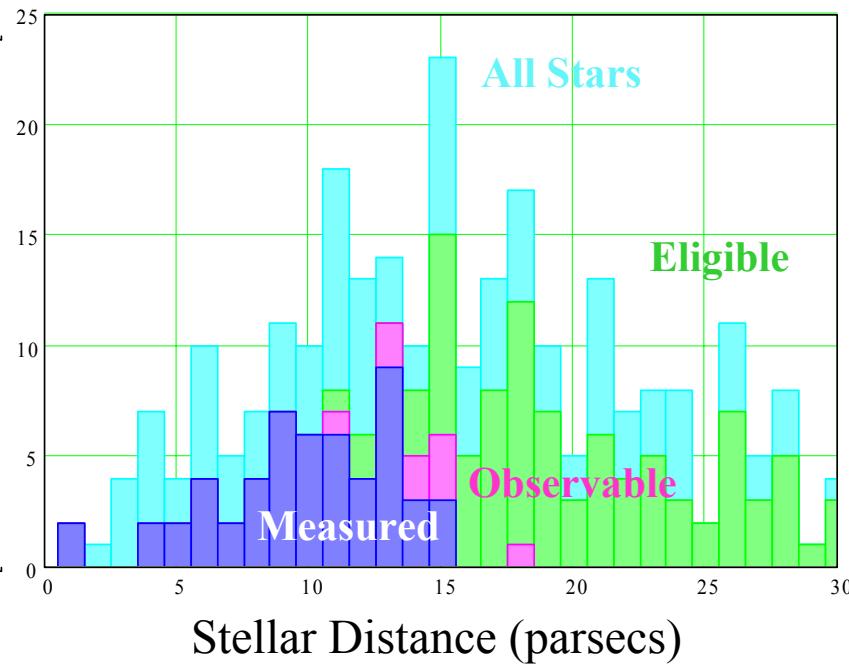


Statistics of the Minimum Mission

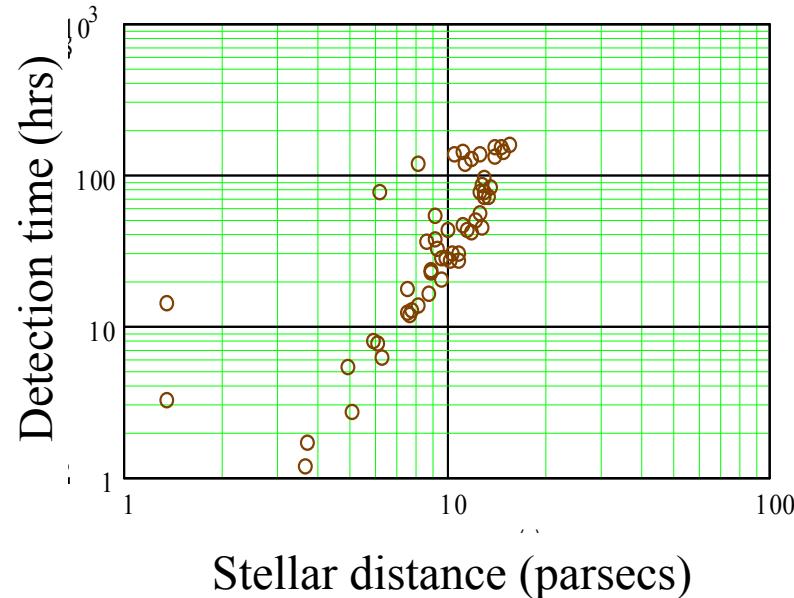
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Histograms of star sets

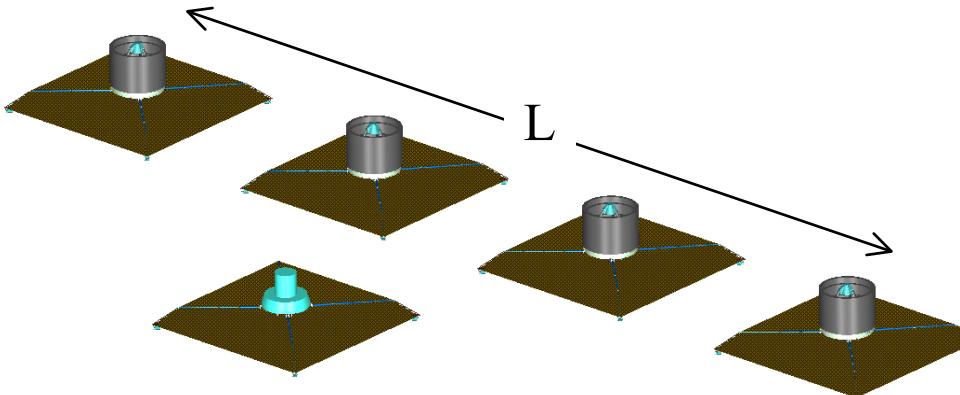


Detection times



Full Mission Strawman

Terrestrial Planet Finder Mission



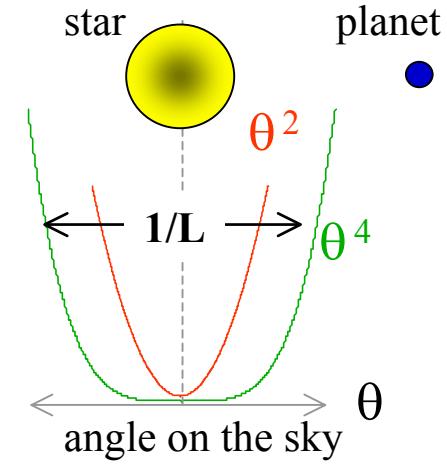
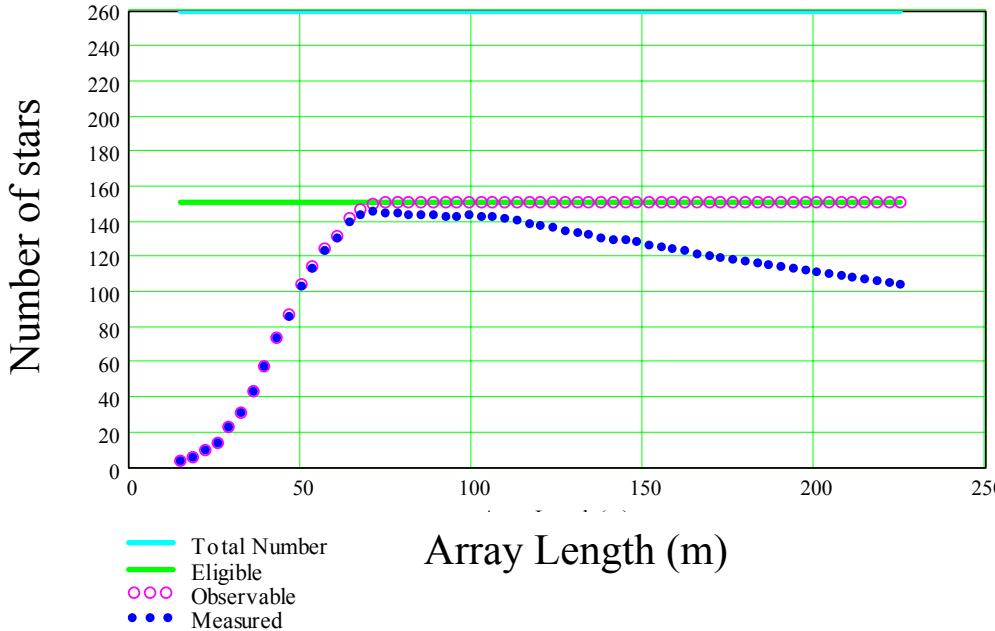
- Four apertures, 4.0 m diameter
- Dual-Chopped Bracewell

$L > 70\text{m}$

$\theta^2 \text{ null}$

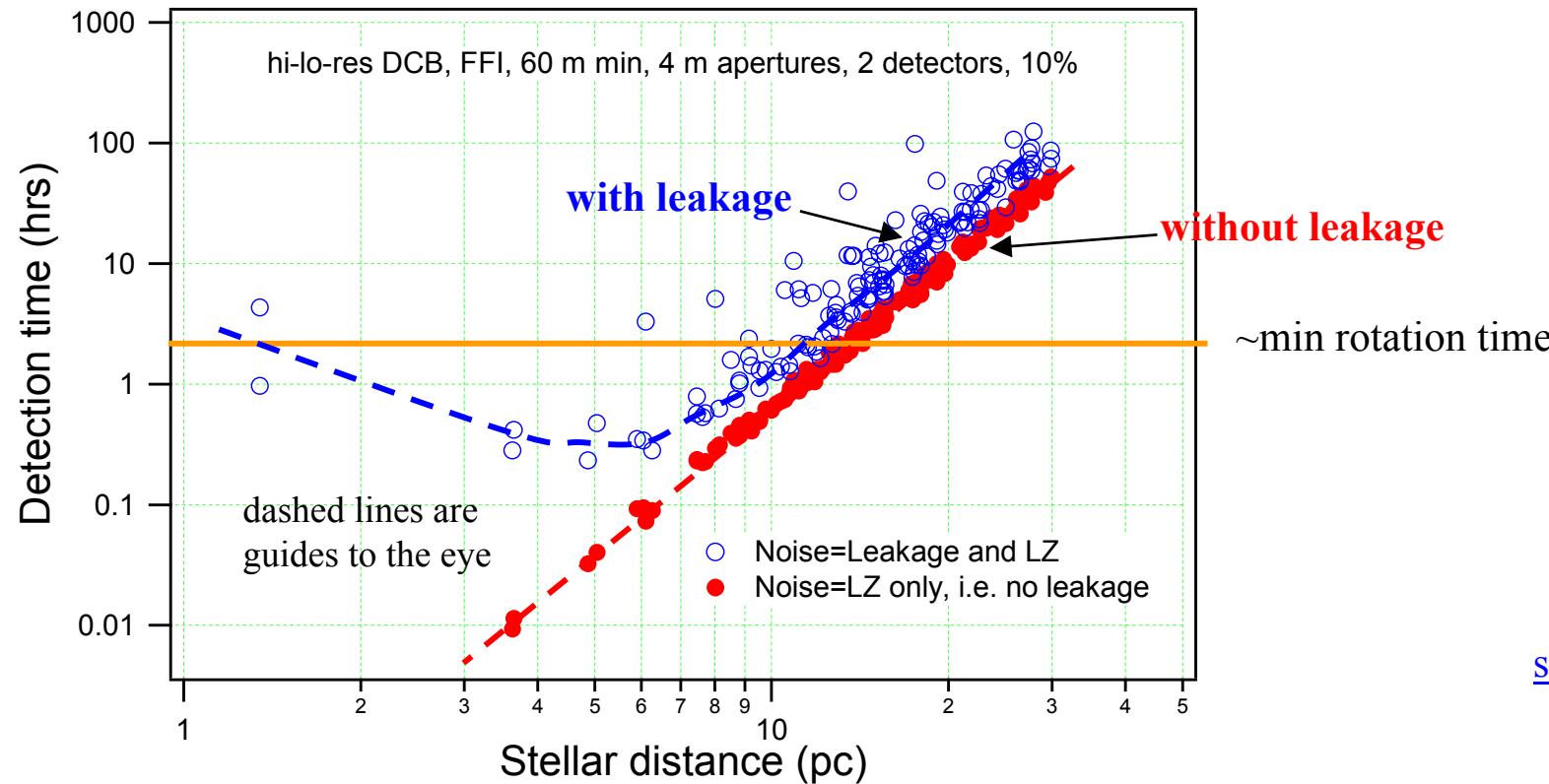
} Stellar Leakage?

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What about Stellar Leakage?



- Although stellar leakage is the dominant noise source for nearby stars, it is NOT a problem for observation of nearby stars.
- More distant stars, which we need to pick up for a full mission, are NOT leakage dominated

θ^2 Configurations should not be ruled out

Full and Minimum Missions

		Structurally Connected Interferometer	Formation Flying Interferometer
Science Capability			
Number of Stars		54	150
Science Assumptions			
Local zodi (MJy per sr, at 12 μm)		14	14
Star List:		modified Ebbets	modified Ebbets
Engineering Assumptions			
SNR for Detection		5	5
Min Wingtip-to-Wingtip spacing (m)		NA	8
Number of visits		3	3
Inclination Factor = (IHZ / IWA)		1.29	1.29
HZ (au) for 95% completeness, half-earth area		0.7-1.5	0.7-1.5
Engineering Parameters (Derived)			
Nulling Architecture		uneven DCB	even DCB
Array size (m)		36	70 to 150
Number of apertures		4	4
Mirror diameter (m)		3.2	4.0
Sky coverage (+/- degrees, from anti-sun)		45	45
Throughput		5%	7%
Integration Time / (2 yrs Calendar time)		50%	75%
Number of detectors		1	2



What's Next

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Terrestrial Planet Finder Mission

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- Freeze strawman architectures, but keep evaluating improvements and alternatives
- Upgrade Stars Selectors analysis
 - Explicitly incorporate exo-zodi and thermal background
- Common ESA/NASA approach to full mission
- Technology testbeds effectiveness evaluation
- Flight design capability assessment



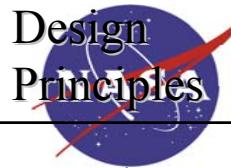
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Mission

Backup slides



Parameters used as input to Strawman Design

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Terrestrial Planet Finder Mission

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Feature	Interferometer	Coronagraph
SNR/visit	5	5
Inner HZ	0.7 "AU"	0.7 "AU"
IWA/IHZ	1/1.29	1
IWA Defined	$\frac{3}{4} \frac{\lambda}{L_o}$ (for hi-res Bracewell)	$\frac{3}{4} \frac{\lambda}{L_o}$
IWA	43 mas for 36m structure	82 mas for 6m aperture
λ_o	10 μm	0.8 μm
Outer HZ	1.5 "AU" (not yet a filter)	1.5 "AU" (not yet a filter)
Visits (for completeness)	3	11
Total time for survey	Elapsed observing time is 1 yr out of 2 calendar yrs	Elapsed observing time is 1 yr out of 2 calendar yrs
Planet surface area	Half earth	Half earth
Field Of Regard (from anti sun)	+/- 45 deg	+/- 85 deg